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TITLE

SPRAYING WITH VARIOUS PENETRATING
OILS IN THE SEARCH FOR A BETTER METHOD
OF CONTROLLING THE MOUNTAIN PINE BEETLE
IN LODGEPOLE PINE

1939

by

Archie L. Gibson
Assistant Entomologist

Forest Insect Laboratory
Coeur d'Alene, Idaho
March 11, 1940

Entomol.

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FOREST INSECT LABORATORY,
PORTLAND, OREGON

File No. _____

Noted by _____

JLW
RLF

Forest Insect Laboratory
Coeur d'Alene, Idaho
March 18, 1940

Dr. F. C. Craighead

Washington, D. C.

Dear Dr. Craighead:

I am enclosing two copies of a report by Mr. Gibson covering the experimental work with penetrating sprays that was conducted on the Teton National Park last spring.

You will recall that at the time of your visit we examined a number of these trees, but felt that definite conclusions could not be drawn because there were a number of complicating factors. It was recognized at the time these experiments were conducted that they were not overly satisfactory due to conditions that were beyond our control. However, Mr. Gibson has worked up these data and they are being submitted for your consideration.

We should be pleased to have your comments and assure you that we are anxiously awaiting the information that you stated you would have available for us concerning the experiments that have been conducted recently at Tallulah.

Respectfully yours,

JAMES C. EVINDE
Senior Entomologist

Enclosures

cc to:

Portland, Berkeley, and
Fort Collins Laboratories

SPRAYING WITH VARIOUS PENETRATING
OILS IN THE SEARCH FOR A BETTER METHOD
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IN LODGEPOLE PINE
1939

In the effort to improve present methods of combating the mountain pine beetle in lodgepole pine, a number of penetrating sprays have been tested. In general they consist of a fuel or Diesel oil base which acts as a carrier for a smaller amount of more lethal ingredients. Certain formulae have given good results, but it was in the hope of developing cheaper, more effective formulae and in simplifying the technique of application that the experiments with penetrating sprays have been continued. In 1939 some new formulae and variations of others which have already given good results were tested. The variations consisted chiefly of adding a wetting agent to the spray, which, by reducing the surface tension of the oil, was expected to promote its more rapid and thorough penetration of the bark, with resulting greater control of the infesting brood.

A second variation consisted of reducing the amount of lethal material in the oil in order to find the minimum amount necessary to give satisfactory control. New formulae were mainly those suggested by Dr. Ormskirk as well as some that had shown promising results in other fields of insect control.

The Windy Point area of the Grand Teton National Park was selected for the experiments. They were conducted on the same basis as in the preceding year--treating one side of an infested tree and

comparing the data from it with those from the opposite untreated side. The data were obtained by removing a definite area of bark and recording number, status and stage of development of bark beetle brood, parasites and predators. In addition to the preceding data, bark thickness and moisture, secondary insects, and the work of the latter and wood-peckers, were recorded. To establish the representativeness of the intensive sample an extensive examination was made of the treated areas adjoining.

Treatment of the trees was conducted from July 15 to 16, examination of the untreated side between the 18th and 23rd, initial examination of the treated side on the 24th and 25th and the second and final sampling on August 5 and 6. This second sampling of treated areas was made only on trees which harbored survivors when the first examination was made.

Due to proximity to time of emergence it was necessary to examine the untreated area very soon after treatment. Postponement to the time when the treated areas were examined would have necessitated counting emergence holes. Where brood is heavy there is no accurate index of how many beetles use the same emergence hole, thus making estimates of brood which has emerged, unreliable. For this reason check or untreated areas were examined first, and the treated areas, on which the brood had in many cases been retarded in development, if not killed by the oil, were examined later.

The oil which formed the base or carrying agency for the lethal ingredients of the formulae is the commercial fuel oil or Diesel grade of 27°+ Baume gravity.

Mortality resulting from spraying, shown in the tables on the succeeding pages, usually comprises data from two examinations. A second examination was usually made of trees showing survival in the treated area when examined the first time. Data from the second examination were then combined with those from trees showing no survival the first time to provide an aggregate that is considered representative of the control obtained.

THE EXPERIMENTAL TREATMENTS

(1) Formula - J (Dichloroethyl ether 1-part
 Fuel oil 4-parts

Data from the ten trees treated with this formula show excellent control. One emergence hole on each of two trees were the only indications of survival and they may have been made prior to treatment. Even if they represent survivors of the treatment the control obtained was 97.2 percent. A composite of the data is shown in table I.

TABLE I
 DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED
 LODGEPOLE PINE SPRAYED WITH FORMULA - J
 GRAND TETON PARK - 1939

| Untreated side | | | Treated side | | |
|-----------------|---|------|--------------|----|-------|
| Living | : | Dead | Living | : | Dead |
| Lar. | : | Pup. | N.A. | : | Total |
| : Lar. | : | Pup. | N.A. | : | Total |
| = .9 | : | 22.8 | 23.7 | .9 | ; .6 |
| Percent living: | | | | | |
| and dead | : | : | : | : | : |

* Emergence holes made by new adults.

Practically all of the data from the ten trees fell within allowable limits of variation, but in spite of that the writer is reluctant

to recommend this formula on the basis of the one test. Further tests with this spray are suggested and if it again proves effective then reduced amounts of the dichlorethyl ether with the oil should be tried because the approximate \$0.50 per gallon cost of the present formula is too high to permit its general use.

Seven of the ten trees treated with the above spray showed light survival when the first examination of the treated area was made. A second sampling of the treated area, twelve days after the first one, of seven $1\frac{1}{4}$ -square-foot bark samples in seven trees, showed only one surviving insect and one emergence hole. The latter might have been made prior to treatment. Even considering both the above as survivors, the control secured was about 98 percent, an excellent showing.

The data are shown in condensed form in table II.

TABLE II
 DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED
 LODGEPOLE PINE SPRAYED WITH FORMULA A-2,
 GRAND TETON PARK - 1939

Consistently good results with twice the amount of orthodichlorobenzene and naphthalene used in this mixture indicate the general

effectiveness of these ingredients. If this formula with its reduced amount of lethal materials can be found as effective under control project conditions, as the formula containing more lethal ingredients the cost of the spray needed would be nearly 25 percent less than that of the formula used on the Grand Teton project in 1939.

On the basis of reasonable cost and effectiveness I consider this the most promising formula tested.

(3) Formula A-2-T (2% by weight of wetting agent (Santomerse D)
(Other ingredients same as A-2.)

The addition of the wetting agent to Formula A-2 showed, statistically, no significant difference in the results obtained by its use and without it. With both formulae, however, giving such nearly perfect results it could hardly be expected that the influence of the wetting agent could be measured accurately. Tests with still further reductions in the ratio of lethal materials to oils will be necessary in order to adequately evaluate the effect of the wetting agent.

The results of spraying with Formula A-2-N are shown in table III.

TABLE III
 DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
 PINE SPRAYED WITH FORMULA A-2-N
 GRAND TETON PARK - 1979

| Brood per square foot on | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|---|------|---|--------------|---|-------|---|--------|---|------|---|------|---|-------|---|---|---|---|---|---|---|-----|---|-----|---|------|---|------|-----|--|
| Untreated side | | | | Treated side | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Living | ; | Dead | ; | Living | ; | Dead | ; | Living | ; | Dead | ; | | | | | | | | | | | | | | | | | | | |
| Lar. | : | Pup. | : | N.A. | : | Total | : | Lar. | : | Pup. | : | N.A. | : | Total | | | | | | | | | | | | | | | | |
| 12.0 | : | 2.2 | : | 37.8 | : | 52.0 | : | - | : | - | : | .7 | : | .7 | : | - | : | - | : | - | : | 1.7 | : | 1.3 | : | 58.0 | : | 61.0 | | |
| Percent living | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | |
| and dead | : | 98.6 | : | | | | : | 1.4 | : | | | | : | | | : | - | : | | | | : | | | : | | | : | 100 | |

Although the attempt to test the effectiveness of the wetting agent was of no avail, the results do further confirm the efficiency of Formula A-2.

It is suggested that the wetting agent be tested in sprays containing a smaller proportion of orthodichlorobenzene and naphthalene to fuel oil.

| | |
|-----------------|---|
| | (25% Pentachlorophenol by weight) |
| (4) Formula - K | (20% Diphenol " " |
| | (20% Toluene " " |
| | (55% Fuel oil " " |

Nine days after these ten trees were sprayed only two showed any survivors in the treated portion examined. Twelve days later another sampling of those two trees failed to show any survivors, but did reveal two emergence holes which, however, could have been made prior to treatment. Even considering them as being caused by survivors of the treatment, the control was over 95 percent. The data are shown in condensed form in table IV.

TABLE IV
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LONGLEAF
PINE SPRAYED WITH FORMULA - K
GRAND TETON PARK - 1939

| Brood per square foot on | | | |
|--|-----------------------------|-----------------------|---------|
| Untreated side | | Treated side | |
| Living | Dead | Living | Dead |
| Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total | | | |
| 6.9 : 2.3 : 13.1 : 22.3 | - : - : - : - : - : - : .5* | .5 : 4.0 : 1.6 : 18.8 | : 25.4 |
| Percent living : | : | : | : |
| and Dead | : 100 : | : - : | : 1.8 : |
| | | | : 98.2 |

* Possibly made prior to treatment

This formula gave excellent results, but a present retail price of about \$0.85 per gallon prohibits its general use.

(5) Formula K-1 (20% Dichenol by weight
 (20% Toluene by weight
 (60% Fuel oil by weight

Only wet and green areas in two of the ten trees treated harbored any survivors under bark treated with the above formula. Later one tree revealed no survivors, but no data were available from the second tree due to lack of suitable treated areas for a second examination. Even on the basis of the insects noted in the one tree, not examined a second time, having survived the treatment, the control obtained was about 91.5 percent. It is likely that the ultimate mortality was much higher. The data secured are given in table V.

TABLE V
 DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
 PINE SPRAYED WITH FORMULA K-1
 GRAND TETON PARK - 1939

| Brood over square foot on | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------|---|------|--------------|------|------|-------|------|---|------|---|------|---|-------|---|-----|---|---|---|---|---|-----|---|-----|---|----|---|------|---|------|------|---|--|
| Untreated side | | | Treated side | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Living | : | Dead | Living | : | Dead | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lar. | : | Pup. | : | N.A. | : | Total | Lar. | : | Pup. | : | N.A. | : | Total | | | | | | | | | | | | | | | | | | | |
| 10.2 | : | 3.6 | : | 29.8 | : | 43.6 | - | : | - | : | .7 | : | .7 | ; | 3.1 | : | - | : | - | ; | 3.1 | : | 6.2 | : | .3 | ; | 25.8 | : | 33.2 | | | |
| Percent living: | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | : | | | |
| and Dead | : | 98.4 | : | | | | : | | : | | | : | | : | | : | | : | | : | | : | | : | | : | | : | | 91.5 | : | |

While the control obtained may be considered effective, the retail cost of about \$0.85 per gallon makes general use of this formula prohibitive and at the same time offers no advantages over equally effective formulae costing less than half as much.

(6) Formula K-2 (70% Fuel oil by weight
 (15% Diphenol "
 (15% Toluene "

This formula carries the same lethal ingredients as the preceding one but in reduced amounts. In control effectiveness it equalled the preceding one, examination revealing survivors only in the wet and green areas. A cost of about \$0.70 per gallon still makes its cost prohibitive at retail prices.

Data concerning this treatment are shown in table VI.

TABLE VI
 DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
 PINE SPRAYED WITH FORMULA K-2
 GRAND TETON PARK - 1939

| Broad per square foot | | | | | | | |
|--|----------|--|--------------|------|---------|--|--------|
| Untreated side | | | Treated side | | | | |
| Living | Dead | | Living | Dead | | | |
| Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total | | | | | | | |
| 16.6 : 4.0 : 23.4 : 44.0 : - : - : .3 : .3 : - : - : 2.3 : 2.3 : 7.4 : 7.7 : 26.9 : 42.0 | | | | | | | |
| Percent living: | | | | | | | |
| and Dead | : 99.3 : | | : .7 : | | : 5.2 : | | : 94.8 |

* Includes survivors in one tree which could not be examined a second time due to lack of additional infested bark.

In spite of the inclusion of data which it is believed represent some insects which would eventually have succumbed to the action of the oil, the control obtained was nearly 95 percent.

(7) Formula K-3 (10% Diphenol by weight
 (10% Toluene "
 (80% Fuel oil "

This formula, comprising a still further reduction in the lethal ingredients, showed the effect of that reduction in the lowered mortality noted. However, the spray may prove more effective than the

data indicate because not only were most of the survivors in wet or green areas but over 75 percent of the living were larvae apparently retarded or arrested in development by the action of the spray. It is likely that a large part of the larval stage will die, in which case the control would be well over 90 percent. The data, including those of treated areas in which a second examination was made, are given in table VII.

TABLE VII
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
PINE SPRAYED WITH FORMULA K-3
GRAND TETON PARK - 1939

| Brood per square foot on | | | | | |
|---|------|---|--------------|------|---|
| Untreated side | | | Treated side | | |
| Living | Dead | : | Living | Dead | : |
| Lar.:Pupl:N.A.:Total:Lar.:Pupl:N.A.:Total:Lar.:Pupl:N.A.:Total | | | | | |
| 7.3 : 1.3 : 36.7 : 45.3 : - : - : .3 : .3 : 9.5 : 1.5 : 1.3 : 12.2 : 29.3 : 2.1 : 18.7 : 50.1 | | | | | |
| Percent living: | | | | | |
| and dead - : 99.3 : - : - : .7 : - : 19.6 : - : 100.4 | | | | | |

Although a greater interval between treatment and examination might reveal much better control, the retail cost of about \$0.58 per gallon of this formula makes its use uneconomical, in view of the cheaper more definitely effective formulae available.

(5) Formula L (Fuel oil 8 parts
 (Orthodichlorobenzene 1 part
 (Monochlornaphthalene 1 part

The late treatment of these trees left results in an uncertain state, as 60 percent of the credited survival is due to emergence holes which may have been made prior to treating. Twenty-seven percent of the brood, estimated as surviving, were sickly, due to the effects of the oil. If the emergence holes were made prior to treatment and the

sickly brood died, the control secured would have been over 95 percent, which is excellent.

The data are shown in table VIII.

TABLE VIII
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
PINE SPRAYED WITH FORMULA L
GRAND TETON PARK - 1939

| Brood per square foot | | | | | | | | | | | | | | | | |
|-----------------------|---|------|--------------|-------|------|---|------|------|-------|------|-----|------|------|-------|------|------|
| Untreated side | | | Treated side | | | | | | | | | | | | | |
| Living | : | Dead | Living | : | Dead | | | | | | | | | | | |
| Lar. | : | Pup. | N.A. | Total | Lar. | : | Pup. | N.A. | Total | Lar. | : | Pup. | N.A. | Total | | |
| 15.1 | : | 3.4 | 12.3 | 30.8 | - | - | 3 | .3 | - | - | 3.0 | 3.5 | 2.1 | - | 10.4 | 12.5 |
| Percent living: | : | | | | | | | | | | | | | | | |
| and dead | : | 99.1 | | | | | | .9 | | | | 22.1 | | | | 77.9 |

* Chiefly emergence holes and sickly brood.

In view of a cost of about \$0.51 per gallon it would be un-economical to use this formula for spraying, with less expensive sprays offering at least equal effectiveness.

(2% Pentachlorphenol by weight
(9) Formula N (98% Fuel oil " "

This formula gave good results but is slow in action. Of the ten trees treated five showed an average of 66 percent control when the first examination was made but 87 percent when examined a second time, twelve days later. Combining the data from the second examination of the five trees with the data from the five trees showing 100 percent control when examined the first time, gave an average of about 92.5 percent mortality. Of the survivors, 60 percent were larvae, 2/3 of which were in wet areas. A still greater interval between treatment and examination would probably have shown even higher mortality.

The data for this treatment are shown in table IX.

TABLE IX
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LONGFOLI
PINE SPRAYED WITH FORMULA N
GRAND TETON PARK - 1939

| Brood per square foot | | | | | | | | | | | |
|--|---------|---|---|--------------|------|---|--|----------------|------|--------------|------|
| Untreated side | | : | | Treated side | | : | | Untreated side | | Treated side | |
| Living | Dead | : | | Living | Dead | : | | Living | Dead | : | |
| Lar.:Pun.:N.A.:Total:Lar.:Pun.:N.A.:Total:Lar.:Pun.:N.A.:Total:Lar.:Pun.:N.A.:Total | | | | | | | | | | | |
| 4.5 : 2.9 : 14.7 : 22.1 : - : - : 1.1 : 1.1 : 2.0 : .3 : 1.0 : 3.3 : 7.7 : 6.0 : 25.3 : 42.0 | | | | | | | | | | | |
| Percent living and dead | : 95.1% | | : | : 4.6 | | : | | : 7.4 | | : | 92.6 |

The good results obtained with this formula warrant further tests.

Its low cost of about \$0.16 per gallon indicate it may prove the most economical of any so far tested. It is suggested, however, that further tests include a formula containing at least 50 percent more pentachlor-phenol and if possible another containing 100 percent more of this lethal material. In addition, the use of a wetting agent with the formula may increase control.

(10) Formula N (Xylol (Xylenes) saturated with (naphthalene flakes at 60° F.....1 part by volume

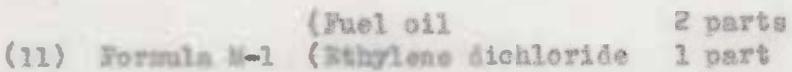
This formula was tested in the search for a cheaper solvent of naphthalene flakes than orthodichlorobenzene. Results obtained place it on the border line of effectiveness due to insufficient data to show the final effect of delaying brood development. Six of the ten trees treated showed 74.7 percent mortality on July 25, which had increased to 83.3 percent by August 6, when a second examination was made. Some of the survival is credited to emergence holes which may have been made

prior to treatment. It is believed that considerably over 90 percent mortality would have been recorded as a final control figure if the time between treatment and examination had been longer. The data are shown in table X.

TABLE X
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
PINE SPRAYED WITH FORMULA K
GRAND TETON PARK - 1939

| Brood per square foot | | | | | | | | | | | | | | | |
|-----------------------|------|--------|--------------|------|------|--------|-------|------|------|--------|-------|-------|------|------|------|
| Untreated side | | : | Treated side | | | | | | | | | | | | |
| Living | Dead | : | Living | Dead | | | | | | | | | | | |
| Lar. | Pun. | : N.A. | Total | Lar. | Pun. | : N.A. | Total | Lar. | Pun. | : N.A. | Total | | | | |
| 3.6 | 1.6 | : 66.0 | 71.2 | - | - | : .4 | .4 | 1.8 | .3 | 1.8 | 4.0 | : 4.9 | .3 | 14.8 | 20.0 |
| Percent living | | : | | | | : | | | | | | : | | | |
| and dead | | : | 99.4 | | | : | .6 | | | | | : | 16.7 | | 83.3 |

Regardless of the final results from this formula a comparison with Formula A-2 shows mylene is not as rapid in action as orthodichlorobenzene. The latter has been found to be quite toxic to bark beetles but most effective when mixed with naphthalene flakes. Xylene as the solute does not seem to possess similar qualities. However, it warrants further tests.



Results from tests with this formula in 1938 were very favorable. In 1939 all trees showed more or less survival and only 61 percent control when the first examination of treated areas was made. The second examination revealed 87 percent mortality and only two trees containing survivors in treated areas. From this increase in mortality and the

large ratio of larvae to other surviving stages, considerable further mortality could be expected.

Results obtained warrant further tests, because of the comparative cheapness (\$0.35 per gallon) of the formula.

The data secured are shown in table XI.

TABLE XI
DATA FROM TEN MOUNTAIN-PINE-BEETLE-INFESTED LODGEPOLE
PINE SPRAYED WITH FORMULA M-1
GRAND TETON PARK
1939

| Breed per square foot | | | |
|---|----------|--------------|----------|
| Untreated side | | Treated side | |
| Living | Dead | Living | Dead |
| Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total | | | |
| 5.2 : 6.5 : 37.2 : 48.9 : .3 : - : .3 : .6 : 3.6 : - : 1.9 : 5.5 : 1.1 : .7 : 35.7 : 37.5 | | | |
| Percent living: | : | : | : |
| and dead | : 98.8 : | : 1.2 : | : 12.7 : |
| | | | : 87.3 |

(12) Formula M-1 = (Fuel oil by volume - 2 parts
 (Ethylene dichloride " - 1 part
 (Wetting agent (by weight) 25
 ((Santomerse D)

Although a few living insects were present and no apparent reason for their survival could be seen, the control obtained was quite good. Nine trees showed survivors at the time of the first examination and five when the second one was made. However, at the latter time few insects were involved. Mortality rose from 71 percent when the first examination was made to 93 the second time. Further mortality would almost certainly have occurred with a longer period between treatment and examination.

The value of the wetting agent is difficult to measure due to the variability of the small amount of data. Analysis of data from the formula with and the other without the wetting agent reveals data from individual trees falling outside of allowable statistical limits of variation. This condition has been found to be quite common to data concerning the mountain pine beetle in lodgepole pine. It was felt the data were insufficient to warrant further analysis other than to state that results obtained with the two formulas were quite similar and no evidence of effect of the wetting agent could be measured.

The data from the treatment are shown in table XII.

TABLE XII
DATA FROM TEN MOUNTAIN PINE BEETLE INFESTED LODGEPOLE
PINE SPRAYED WITH FORMULA M-1-N
GRAND TETON PARK
1939

| Brood per square foot | | | |
|---|---------|--------------|--------|
| Untreated side | | Treated side | |
| Living | Dead | Living | Dead |
| Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total:Lar.:Pup.:N.A.:Total | | | |
| 14.0 : 2.7 : 0.3 : 57.0 : - : .7 : .6 : 1.3 : .9 : .6 : 1.6 : 3.1 : 1.6 : 1.5 : 32.6 : 36.0 | | | |
| Percent living: | : | : | : |
| and Dead | : 97.7: | : 2.3: | : 7.0: |
| | | | : 93.0 |

(13) Fuel oil alone and in combination with a wetting agent were tested but found to cause insufficient control. The wetting agent not only failed to increase the control secured but trees treated with it as part of the oil ingredient showed less control than where only oil was used. However, the wide variation in results in individual trees with both treatments prevent an accurate statement as to the effectiveness of the wetting agent.

DISCUSSION OF RESULTS

Based on control obtained and relative cost, formula A-2, composed of orthodichlorobenzene and naphthalene flakes in fuel oil, gave the best results. These are the same ingredients, although in reduced amounts, that have produced consistently good results in experiments that have been conducted for a number of years. It is felt that the control obtained has been sufficient to warrant a large scale test of the formula on a control project.

Slightly better control but higher cost were noted for the above formula to which a wetting agent had been added. However, to secure an adequate evaluation of the effectiveness of the wetting agent, reduced amounts of the lethal materials in the fuel oil carrier, both with and without the wetting agent, should be tested.

Costing less, but somewhat lower in control effectiveness, formula H, comprising 2 percent by weight of pentachlorophenol in oil, gave surprisingly good results and should be given further tests. In addition, increased amounts of the lethal agent in fuel oil should be tested.

Another formula which proved quite effective combined fuel oil and dichlorethyl ether. However, in its present form this spray is too expensive for general use but reduced amounts of the lethal agent may prove equally effective and lower the cost to acceptable limits.

Four other formulas, K-2, H-1-H, H and K-1, gave acceptable results as far as control effectiveness is concerned, but high cost precludes their general use. Relative ratings are given for each formula in table XIII.

TABLE XIII
 RELATIVE RANK OF THE VARIOUS FORMULAE TESTED
 IN 1939 ON BASIS OF EFFECTIVENESS OF
 CONTROL AND COST PER GALLON - GRAND TETON PARK
 MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

| Formula number in report: | Percent control secured | Approximate mate cost: per gallon | Rating as to Control: | Cost: | Final rating |
|---------------------------------|-------------------------------|---|--------------------------|-------|-----------------|
| J | 97.2 | .50 | 4 | 7 | 4 |
| A-2 | 98.0 | .22 | 3 | 2 | 1 |
| A-2-W | 100.0 | .31 | 1 | 5 | 2 |
| K | 98.2 | .15 | 2 | 11 | 6 |
| K-1 | 91.5 | .85 | 8 | 11 | 8 |
| K-2 | 94.8 | .70 | 5 | 10 | 7 |
| K-3 | 80.4 | .58 | 11 | 9 | 9 |
| L | 77.9 | .51 | 12 | 8 | 9 |
| M | 92.6 | .16 | 7 | 1 | 3 |
| R | 83.3 | .26 | 10 | 3 | 6 |
| M-1 | 87.3 | .30 | 9 | 4 | 6 |
| K-1-W | 93.0 | .36 | 6 | 6 | 5 |

FURTHER TESTS

Of the fourteen formulae tested in 1939 it is felt that only four, A-2, A-2-W, H, and J, should be given consideration for further tests at present. These tests should include the variations discussed in this report.

Four of the remaining ten formulae, K-2, K-1-W, K, and K-1, may be given further tests provided the cost of the lethal ingredients can be lowered to the point where it is economical to use the formula.

SUMMARY

Tests conducted in 1939 in the search for improved methods of controlling the mountain pine beetle in lodgepole pine revealed a number of penetrating oil sprays which gave satisfactory control. Three of the fourteen sprays tested were comparatively low in cost. Five others were more expensive, but some of these offered the possibility of equal control and lower cost by reducing the amount of the more costly ingredients in the formula. The four most effective formulas gave an indicated mortality in excess of 97 percent and an additional four exceeded 91 percent.

Experiments designed to measure the effectiveness of wetting agents in augmenting control failed because differences in results obtained between formulas containing and without the wetting agent were not significant.